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CASE STUDY

ESTABLISHING A PROGRAMME OF MICRO HYDRO ELECTRIC POWER DEVELOPMENT FOR RURAL ELECTRIFICATION IN SIERRA LEONE*

by

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SUMMARY

This paper has set out to describe the possibilities and efforts being made in adopting micro-hydro power plants as the basis for the electrification of the rural areas of Sierra Leone. There is no doubt the fact that the potential exists for a widespread installation of micro-hydro plants in rural Sierra Leone and that the basic hyman resources and infrastructure necessary to initiate home manufacture of some components also exists in the country. Naturally, there are many obstacles in introducing micro-hydro plants especially for the fact that not many people realize its potential. Hence until an installed pilot plant is seen to operate successfully, many people will not be interested and because of this reason, it will be difficult to finance these initial stages from local sources. This is the reason behind efforts at the University of Sierra Leone to involve Government Departments and at any stage keep them aware of progress to the realization of the project. Once the potential value of micro-hydro plants is realised through a pilot demonstration plant, it is expected that this would attract more attention. At this stage, it would also be possible to involve local rural inhabitants to whom the amenity is primarily intended.

In planning a widespread application and long-term involvement in micro-hydro, consideration is given the developments already attained in parts of the developed world and the possibility of establishing a local manufacturing industry. Only then can such construction and installation cost reductions be made as to render this service within the purchasing power of rural inhabitants, Manufacture of components at home provides the country with an

industry that is well suited to its resources and needs. The efficiency of such home-built equipment would be lower than imported units but considerable capital cost reductions are achieved. Such local manufacturing effort will require at least at the initial stages, the technical co-operation and assistance of outside institutions who have had longer experience in MHG plant technology. While stressing the need for local manufacture of components, quality and reliability of equipment are also important considerations in this programme. Before widespread applications in rural communities, any such home-built plants must have well proven operating characteristics.

To further encourage the widespread installation of MHG plants and to increase the usefulness of these plants to rural inhabitants, the Faculty of Engineering will undertake the development of suitable equipment that would depend on the resulting electricity as energy input. Such applications would include the use of electricity to provide power for small agro-based industries, blacksmitting and carpentry workshops, pumps for water supply and irrigation etc.

As much as possible, the wider field application of MHG schemes must be on aided self-help basis i.e. villagers with some Government financial and technical support, must be fully involved in the planning and implementation of the programme in the form of providing some of the costs of equipment and of course providing labour. This is important to ensure that the full benefits of the scheme reaches the majority of the population if possible free of charge.

INTRODUCTION

Sierra Leone is situated on the Atlantic Coast of West Africa from 7^{o} to 10^{o} latitude North and from 10^{o} to 13^{o} longitude West. Along the Coast, there are a number of islands and peninsulas, the most important of which is the Western area, a mountainous area where the capital "Freetown" is situated. The area 50 - 100 km. inland, except the Western area, are mainly plains, so that the tidal influence can be observed up to 50 km. inland. The north eastern part of the country is a plateau with the two most important mountain massives the Tingi and Loma mountain ranges. The peaks of these mountains reach up to 1850 and 1950 meters above sea level respectively. The climate is tropical with a wet or rainy season lasting from April to November and a dry season for the balance of the year. A wide fluctuation occurs in stream flow between the dry and wet seasons. Some streams all but dry up during a prolonged dry season. During the wet season, these same streams occassionally overflow and become raging torrents. Due to the humid climate and an average rainfall of up to 4,000 mm per year (amongst the highest in Africa), the drainage network is very dense. The primary drainage of the plateau belt is roughly from North to South, with a secondary drainage from East to West. These drainages descend from the plateau belt towards the coast, occasionally in a series of falls, cascades and cataracts. About 80% of the land area of the country lies within the watersheds of seven major rivers. Most of these rivers cascade down the relatively steep break from the plateau belt to the intercontinental belt, displaying extensive natural power potential.

Although the country is blessed with an abundance of water resources especially for micro-hydro electric schemes, very little has been done so far to develop them. The development of potential

micro-hydro sites is a key asset for Sierra Leone and will go a long way to providing power in rural areas. Several mineral deposits have been discovered in different parts of the country, the most important of which are alluvial diamonds, iron ore, bauxite and rutile. Unfortunately, there are no energy minerals like coal or oil. Thus energy development is of primary concern for the country. But in developing a stategy to meet future energy demands, it must be emphasized that of a population of 3 million, three quarters of these live in rural areas and these depend directly on agriculture for their livelihood. In Sierra Leone, the electricity capacity and consumption are low. Installed capacity at the end of 1971 was 86.6 mw, with a production of about 217 million kwh. Tarriff rates are relatively high, averaging 7.0 cents per kwh in Freetown and 10.0 cents in the provinces. The cost of electricity being so high, many rural areas because of their remoteness from existing supplies, and because of low earning power of its inhabitant, hardly benefit at all from electrification. A decentralised system of micro-hydro electric power generation offers many advantages for electric power supplies to these areas. Hitherto, only two micro-hydro schemes are in operation in the country. Both are part of a multi-purpose scheme at Guma Valley in the West of Freetown. The primary purpose of the Guma Valley project is to provide domestic water supply for Freetown and its environs. This paper mainly concerns efforts being made in this country, to introduce micro-hydro power development as the basis for the widespread electrification of the rural areas of Sierra Leone. Where it is necessary, reference will be made to the two operating plants in the country.

OUTLINE OF HYDROLOGICAL RESOURCES OF THE COUNTRY

With its heavy rainfall and rugged topography, Sierra Leone has a vast water power potential, the bulk of which occurs on the large river systems. There are also many sites suitable for the installation of micro-hydro electric plants. A major impediment to water resources development has been the lack of basic data. Hydrologic as well as meteorological observatory stations have been few and inadequately equipped. Poor access to the remote areas hampers the setting up of these stations, and there is a scarcity of trained staff to collect and compile necessary data.

Prior to 1961, the collection of hydrological data was mostly limited to accummulation of meteorological data. Until the end of 1970, the existing hydrological data in the country was inadequate; no current meter measurements had been carried out, so that there were no stage/discharge relations available and it was impossible to get any accurate run-off results. Some flow measurements had been performed earlier by the London based Howard Humphreys Consulting Engineers but no records are available. In 1971, an evaluation of the hydrological potential of the country's main rivers was undertaken by Motor-Columbus Consulting Engineers. The evaluation was based on existing records together with meteorological and hydrometric data from Guinea and Liberia . As these three neighbouring countries have very similar climatic features, the study provided reliable results especially on monthly discharges and probable discharges of wet and dry periods and on flood flows for the most promising sites. Based on these findings, 20 sites were identified having an aggregate potential of 1,150 mw and it has been recommended that three of these are to be developed

as the first phase to provide the base generation capacities for three regional systems which in the long term would themselves form the nucleus for a national grid system. Some details of computed hydrological data for the year 1971 for five of the proposed sites is shown in Table 1. But in these studies, only larger hydropower schemes i.e. more than 10 mw were considered. Nevertheless, the country offers a considerable potential for small-scale hydropower plants and it was pointed out in the report that although a complete inventing of all the sources for micro-hydro power was not made numerous such sites were observed. These would compete by far more favourably with small thermal power plants. It may not even be exaggerated to say that in general, the topography of Sierra Leone presents better chances for micro-hydro plants than for bigger schemes with the exception of a few sites. Small hydro schemes e.g. up to 1mw, can be designed to operate either on the minimum discharge in the dry season, or utilize small storage reservioirs which are easier to realize.

Since 1971, a hydrologist of the UNDP has carried out measurements as well as the erection and operation of additional statious in the country. Also, realizing the importance of basic hydrological data, a hydrological society has been created, with the objectives of developing a broader programme to collect, compile and publish this information in the form of an annual hydrological report. Surface water investigations are now being undertaken to obtain flow measurements and river stage heights to serve the purpose of long-term development projection for various uses of water resources. Also, river discharge measurements are carried out at a few sites which are equipped with stream gauging equipment.

By virtue of the seriousness attached to the development of the country's hydro-power resources, a UNDP expert, having wide experience in energy systems planning in African countries has recently being assigned to the Ministry of Energy and Power, to assist and advice Government on the strategy to be adopted in fully utilizing the country's hydropower resources.

TABLE 1

HYDROLOGICAL DATA FOR PROSPOSED DAM SITES

	BUMBUNA	KAMOIA	ROKOU	GOMA	BENKONGOR
Catchment Area Km^2	3,700	2,050	7,400	290	6,500
Average Discharge a) monthly m^3/s.					
January	23	12	50	2.6	45
February	10	5	23	1.7	26
March	8	4	21	1.6	23
April	7	4	19	2.0	24
May	25	13	53	3.2	53
June	115	50	280	10	190
July	150	75	410	15	290
August	255	90	860	28	430
September	310	140	830	30	530
October	275	130	700	23	490
November	140	75	310	13	280
December	50	27	110	5.8	100
b) Annual					
Normal	115	52	305	11.5	207
Dry	80	36	210	8.8	150
Wet	160	73	430	14.5	280
c) Maximum Flood	1,150	550	3,200	110	1,800

COUNTRY POLICY AND PROSPECTS FOR THE DEVELOPMENT OF RMG SYSTEMS

The Government's stated policy calls for the decentralisation of economic activity, with an emphasis on improving the quality of life in rural areas through agricultural development and the stimulation of village-level industry. But if such development is to have a major effect on the rural majority, energy must be made available to them in a dispersed form and at low cost. As a general input to infrastructure development and in assisting local small-scale industries electrification ranks high in importance. At present, rural electrification if this means the supply of electricity to the villages in which rural communities live, does not exist in any form nor is there any Government policy as to how this would be achieved. If any such developments are to be implemented in the near future, it is most likely that rural electrification will take the form of decentralised supplies. Electrification is normally achieved by extending the national electricity supply grid to the rural area from the nearest generating facility or through the installation of a small diesel generating plant. Whilst an interconnected national grid system would have many operational advantages, the economic basis for such a system does not yet exist in the country. Even for a decentralised scheme, tariff rates will have to be very low if such schemes are to have any real success in terms of rural electricity demands and a general improvement in the social and economical status of the rural population. This leaves the options of heavily subsidized electrical supplies to rural areas, or for communally financed schemes through aided self-help efforts.

The emphasis in Government policy to promote economic and social development through aided self-help methods would favour the latter alternative but only where the costs involved are within the capabilities of the rural communities concerned. Fortunately the general topographical features of the country is such that such can be achieved in many rural areas by exploiting the small-scale hydropower potential of the country. Investigative work on micro-hydro electric power plants specifically for low-cost decentralised rural electricity supplies, currently underway in the Faculty of Engineering of the University of Sierra Leone is likely to have a major impact and a stimulation of Government attention. A recent circular in the form of a letter on the activities of the Faculty in the field of micro-hydro-power development, to key Government Ministries suggests on felt need for a comprehensive long-term programme of rural electrification with established priorities of projects integrated with the overall national development plan.

Hitherto, diesel sets have been used mainly to provide electricity supplies to larger settlement in rural areas. It has been further proposed to set up micro-diesel stations in other settlements and smaller villages that are not yet electrified. But the energy crisis in 1973 and the ever increasing cost of fuel oil, together with the enormous operational difficulties in addition to the low earning power of village inhabitants has not encouraged any further installation of diesel plants to serve rural communities and may cause Government to reconsider its plans by considering other alternatives. Renewed interests in micro-hydro power plants therefore seems opportuned for further investigations into their suitability as a substitute to thermal plants. A mention of the suitability of micro-hydro plants for rural electrification in Sierra Leone, in a recent

UNDP report on the strengthtening of the Sierra Leone Electricity Corporation might further stimulate Government interest and its adoption in the near future. It was recommended that due regard must be paid to the possible use of small hydro-electric plants in locations that are at present without electricity supplies but where the establishment of such plants may become economically feasible. The value of such micro-hydro plants lies not only in avoidance of fuel costs, and the remoteness of much of the population from any form of public power supply, but also the freedom they give to the rural community to press ahead with development although their neighbours may be indifferent.

Micro-hydro power development has been hampered by a number of reasons. The benefits of low long-term operating cost and non-dependency on the availability of fuel are over-shadowed by the relatively lower initial costs of diesel plant which allow limited capital funds to be spread more widely. Also, the shortage of technical personnel and the comparatively longer period of time required for site and hydrological investigations favour the quick and relatively straight forward choice of diesel equipment. These are indeed true where traditional designs are those adopted for micro-hydro power development. Such a strategy would in fact demand a prohibitively high cost of electricity to the rural consumer to whom the value of service might not be particularly high. Experience in some parts of the world show that home-built or assembled equipment without sophisticated regulators and governors often forms satisfactory substitutes.

Where a micro-hydro power scheme is developed and financed communally through "self-help" efforts, almost everybody is a potential user. In terms of social organination, villages or parts of larger towns can be viewed as an entire community with community - level needs and patterns of ownership. In many rural areas of Sierra Leone,

there will be found groups of people who are related to each other through ties of common descent. Other association within and between villages also exist e.g. craft-members, religious groups etc. and can be the basis of acquisition of electrically operated devices and industries. Of considerable importance however, is the domestic group i.e. the household and family, because they form a basic unit of consumption, distribution and production.

INFRASTRUCTURAL DEVELOPMENTS AND LOCAL MANUFACTURING CAPABILITIES

The most significant infrastructural facility that will have or major bearing on efforts to local manufacture and assembly of micro-hydro plant components is the Sierra Leone National Workshop. The workshop is fully owned by the Sierra Leone Government and it was conceived to make use of available valuable assets i.e. machines and buildings of the now defunct Railway Department and to utilize the Technical manpower skills of its trained personnel particularly those of the former locomotive maintenance workshop. The Railway Workshop had being the training ground for a good percentage of the country's skilled artisans over the years in a variety of Trades and Technical sills. The first task of this change over was the transformation of the Workshop from a maintenance unit to a production unit. The original workshop was basically a Departmental maintenance unit designed and equipped for the maintenance of Railway locomotives and Rolling stock. A number of machines that were not suited to the needs of a production unit otherwise than for Railway purposes were removed and those that were, suitably located. A variety of implements are being produced presently in the Workshop. These include hoes, axes, rakes, picks, shovels, stoves and many other agricultural tools, domestic applicances and home decorative items.

The workshop comprises many sections appropriate to a large workshop. These include Blacksmith, Copper Smith, Carpentry, Electrical, Foundry, General Operations, Machine, Millwright, Plating, tools and gauge makers, welding, vehicle maintenance and repairs, wood working etc. In particular, the Foundry facility at the Workshop gives tremendous dimensions to the capacity of the workshop, both in quality production and variety for major items that would form vital

components of a micro-hydro development project. Following negotiations concluded in 1974 for economic and Technical co-operation between the Hungarian People's Republic and the Government of Sierra Leone, the Workshop was recently provided with the services of three Hungarian technical aid experts. One of these experts is a specialist in Foundary Technology and the others are mechanical Engineers; one specialising in Production Engineering and the other in the maintenance of machines. With the expertise of these Technical Aid personnel, new technologies in Foundary work e.g. the shell moulding and lost wax casting methods are soon to be introduced and the foundry furnaces and cupola modernized. These developments will increase and improve the workshop's scope and quality of production to the point that a large variety of products hitherto being imported into the country will be locally produced for domestic consumption and the eventual export to neighbouring countries. At the moment, the Workshop relies mostly on scrap metals for its raw materials. These are in abundance and there is no immediate danger of critically short supplies in the near future.

The components of the micro-hydro plant with the greatest potentialities for local manufacture are the turbine and casing. A governing system can also be developed that could be manufactured or assembled locally. Penstokes, dams, weirs where required, can be constructed from locally available materials. The generator could perhaps be initially imported but if a widespread programme to install micro-hydro generation schemes gains enough acceptance, it could become justifiable to set up a workshop or upgrade the Electrical section of the National Workshop to build and wind small alternators. The capital investment in such a plant need not be very great as electrical machinery manufacture can be organised on labour - intensive small-scale basis. It is envisaged that generators of the brushless

type would be most suitable since these require less maintenance. Also, six-pole machines will be given primary considerations because these tend to last longer as they need not be driven as fast as their four-pole counterparts. In addition, both direct coupling and the use of pulleys and belt drives for speed increasing are to be investigated. Because the range of power requirements and the topological features around the country are so diverse, it will be worthwhile to investigate the possibilities of manufacturing all the options of low, medium and high head turbines. Pelton wheels are the only installations in the country presently; but low-head propeller or kaplan fixed blade turbines also have great potentialities both from the manufacturing as well as the applications points of view. Besides the advantage of high specific speed, therefore needing less gearing up to drive the generator, the kaplan turbine requires low material content and has the important feature of widely-spaced blades which can readily pass leaves, debris or fish. Because of construction difficulties, the manufacture of Francis turbines which are best at high and medium heads; are not likely to be undertaken soon and not until sufficient skill and facilities have been acquired. Inexpensive coatings could be applied to render the components resistant to erosion and corrosion. In all cases, multiple plain jets rather than complicated and costly adjustible spear values will have many constructional and operational advantages especially at the rural level. For such systems, coarse control could be achieved to cater for seasonal or long-term changes by switching in and out multiple turbines or the number of nozzles deployed with a pelton wheel. Fine and instantaneous control could be achieved by means of an electronic controller.

THE GUMA VALLEY MICRO-HYDRO ELECTRIC POWER PLANTS

Guma Valley is situated about 10 miles West of the centre of Freetown. In 1954, it was proposed to develop the tremendous water potential of this valley to supply the growing domestic needs of Freetown and its environs. An earth dam was built in 1960 and this was expanded in 1965 to create a lake having a maximum capacity of 4800 million gallons and the eventual maintainable yield of 20 million gallons per day, which at that time far exceeded the requirements for Freetown and its environs. The dam was constructed to full capacity in terms of physical and economic size of the lake and taking into consideration any abnormally high yields in the forceable future. There was thus the possibility of the water resources of the lake serving a multi-purpose use at least in the immediate future after its construction but keeping in mind the fact that provision of adequate domestic supplies was the primary objective of the scheme. Power production on a small-scale was most suitable on account of comparable needs for other alternatives to which the surplus water resources could be put. This decision was based on Engineering and economic considerations in appraising alternative and complementary uses as well as in obtaining the inherent economy and greater utilization of resources. In so doing, the plan formulation was primarily to plan and develop the water supply scheme and to plan the power generating facility to match the conditions existing at the dam site. One feature of the design of the water supply scheme was the installation of a micro-hydroelectric plant having a capacity of 100 kw to serve the energy requirements for the water purification plant. Thus the water supply scheme was independent of the public electricity supply system. In addition to this, the Sierra Leone Electricity Corporation installed a 2.6 mw plant that depended on the availability of surplus

water in the lake to provide its motive power. Accordingly, the generating capacity of the plant was chosen taking into consideration future needs for the reinforcement of the domestic water supply and the expectation that when the lake can no longer accommodate surpluses in available water, there would have been enough generation from elsewhere as to render the Guma hydro-power plant only for standby purposes. Unlike the larger SLEC plant, water used to power the prime mover of the 100 kw plant is returned into the processing plant, so that no water is wasted. If the SLEC plant is to be fully utilized throughout the year and if such operation is to continue in the near future, this feature of the 100 kw plant must be incorporated into its design. This feature would also be very desirable in an integrated rural development project and it is envisaged that where possible, future plants will take this form.

These two installations are the only currently operating small-hydro plants in the country. All the components of the MHG plants are of British origin. In addition to these, a small-hydro plant having an installed capacity of 3.4 mw at Dodo in the Kenema District is presently under investigation by Chinese technicians. The details of the construction features of this plant was not available at the time of writing this paper. This plant might not be unconnected with an earlier country wide survey of small-scale-hydro sites which was carried out by the Chinese but the results of which were not published. Both the Guma micro-hydro installations are imported units and they have been in use eversince the second-phase of the scheme was commissioned in 1966. The SLEC unit has eversince operated for more than 25,000 hours. Since the primary objective of the Guma Valley Water Company is to provide domestic water supplies, the SLEC plant operates only when the available water in the reservoir is in excess of

the demand by a safe margin. Consequently, the plant supplies power only in the wet season, approximately six months in the year. Also, as the city expands and the demand for domestic water increases, the power generating facility at this plant will be gradually phased out, until at such a time when surplus water in enough quantities will no longer be available to run the plant. Water for running the plant is drawn through a 36" diameter pipe from the bottom of the dam where the water is highly polluted. The plant is a pelton wheel installation operating on a head of approximately 330 ft. The generator is a three phase, 4-pole, slip-ring synchronous type machine with a horizontal shaft and it is foot mounted, with an installed capacity of 2.6 mw at 0.8 power factor. The output is at 11 kv, 50 Hz and it is designed to operate at 750 r.p.m. normal and a maximum operating speed of 1450 r.p.m. for which an over speed device is provided. The turbine shaft is directly coupled to the generator shaft, thus making the system more efficient and trouble free, compared with any link through gears or belts.

The generator is screen protected and has two pedestal water cooled bearings with journal pads of the tiltig type and lubrication is by oil scooped out of the reservoir in the pedestal by means of a scooped ring on the shaft. The exciter isqlso screen protected with an output of 52 volts and 361 amperes. When it was commissioned, the plant was originally controlled from the SLEC control centre at Kingtom, through a pilot link. But for the last few years, there had been some faults in the pilot link and the control system has since been put out of service, so that the plant is presently started and shut down manually when necessary. Since its inception in 1967, no major operational problems have been encountered but the hydraulic part of the turbine and the main shut-off value are now in a poor condition.

Detrimental cavitation noise occurs from the turbine housing indicating that damage will occur possible within the near future. The mechanical parts of the turbine, the generator and the switchgear are in good order.

The design of the smaller unit having an installed capacity of 100 kw is similar to the SLEC plant. This plant is used exclusively to provide power for the water treatment plant at the works. Because of its relative importance, this unit has been regularly well maintained and no major problems had arizon yet, nor are there any problems foreseen in the near future; although the plant is almost always engaged. Water is fed into the turbine housing of the plant through part of the main pipe leading from the lake on to the treatment works. Thus both the water that is used to power the generators and any surpluses are treated and fed into the water supply system. The generator is presently under-utilized but as the demand for domestic water supply increases, output from the generator will also be increased. Besides, the treatment plant is provided with two standby diesel generators having installed capacities of the same order as the hydro plant.

It is difficult to estimate the installation costs, cost per kw of energy for the Guma Valley micro-hydro plants; because these were part of the more important water supply scheme. The details of exact costs of the installations are not available from records, but in 1967, the cost of equipment for the SLEC plant is estimated at £500,000. This gives an installation cost of £200 per kw of installed capacity. This figure will of course be much less if less sophisticated home built turbines and other auxiliaries were used or where the installation of the plant was by a voluntary national organization.

because the SICC plant operates only six-months in the year, it has not been regularly maintained and no information is available on maintenance costs. This is reflected in the fact that since the necessary routing maintenance has not been adhered to, particularly when the plant is idle, the plant has hardly being through one third of its useful life span whenforeseen operational difficulties begin to manifest themselves. On the other hand, the relative importance of the 100 kw plant has attracted regular maintenance and proper care. Hence its smooth running to date. The running costs for this plant is estimated at £100.00 per annum, less the cost of supervision since it forms only a minute part of the larger water supply scheme. An estimate of the savings made through use of the 100 kw micro-hydro plant can be obtained by considering the cost of running the equivalent diesel plant which serves the treatment plant as standby. It is estimated that the average fuel requirements for the continuous operation of the diesel plant would be 400 litres a day which at present costs would give £150.00. On the other hand, it costs virtually nothing to run the hydro-plant since water used to provide its motive power is fed into the treatment plant. Thus the average savings on fuel alone is in the region of £55,000 per annum.

The total cost of the 3.5 mw plant to be installed by a Chinese team at Dodo has been estimated at £3.4. This gives approximately £1000.00 per kw of installed capacity. Where labour is provided, this figure can be as low as £600.00 per kw of installed capacity. For the systems that are being planned for local manufacture, it is estimated that costs for hardware will be in the range £300.00 to £1000.00 per kw of installed capacity plus a further 50 to 150% depending on site configuration and transmission distance

i.e very approximately, total costs for plant and site work should be in the range of £500.00 to £2,000.00 per kw of installed capacity depending on local material and labour costs, site conditions, size of plant etc. These figures would be far less in the ideal case where labour and local materials can be obtained free of cost, and where national voluntary organisations provide the technical input. On the basis of a 50% average load factor, 10% interest charges and a 20 year amortisation period, this represents a generation cost in the range 1.5 cents to 2.5 cents per kwhr, which is cheap electricity by any standard.

TECHNO-ECONOMIC COMPARISONS FOR THE USE OF MHP AND MICRO-DIESEL PLANTS

In the circumstances prevailing in Sierra Leone, the extension of bulk supplies from central generating stations to remote rural settlements is rendered extremely difficult and expensive. Existing generating facilities will have to be reinforced and the cost of transmission equipment will be prohibitively high only to supply very small and highly scattered loads. For larger towns, electrification has been based on isolated diesel driven generators. The operation of such diesel stations of varying sizes, which are spread over the length and breath of the country is necessarily very costly and usually unprofitable. The cost of administering both supervision and supplies in sparsely populated areas is very high. Besides, the majority of these plants are now in very bad operating conditions and soon, high maintenance and operating costs, together with a shortage of adequately skilled personnel to maintain and repair them will render these plants very unrealiable and economically not viable. Consequently, these problems have also contributed to the low level of electrification and to the limitations of extending supplies to rural areas that are not presently electrified, through the use of isolated diesel plants. To cut down on operating costs, supply in some cases are on twelve-hour basis. Owing to the high costs of generation in these stations, it would be necessary if the systems are to remain in operation, either to change such high rates as would tend to restrict the use of electricity or for Government to subsidize heavily on such improfitable supplies.

Both these approaches are not likely to be practicable. Micro-hydro electric power development; where this is possible; provides

a possible solution that can overcome both the problems of high operating costs and that can encourage widespread use of electricity in rural environments. To justify the installation of micro-hydro plants for rural electrification, it would be necessary to show some advantages over the ubiquitous micro-diesel alternative.

Considering the rapidly escalating fuel costs and the inaccessibility of most of the rural settlements, such comparisons will favour the micro-hydro alternative in the long term. Besides, micro-hydro power will concern development of the country's own resources. Provided there is adequate water head and flow in the dry season, and where it can be assumed that past patterns of stream flow can be expected to re-occur, there is virtually no question about the technical or engineering feasibility for a micro-hydro project at any site since it will consist of only very small structures. Even where there are insufficient hydro-meteorological data, MHG schemes can be planned and developed with proper restraint and judgement. Apart from the fact that the energy is free and inexhausible, micro-hydro plants can be built quickly since the civil works are simple, and their working life is much longer than for diesel plants. The cost of reservoirs, dams and water ways is generally the highest component of total micro-hydro installation cost. But where such an effort is based on "self- help"; dams, penstokes and other civil works if needed, could be constructed with local labour and materials without significant capital costs. An example of such "self-help" projects is shown by experience gained in the establishment of water pumps in the rural areas of Sierra Leone. Some 175 Dempster deep well pumps have been installed in villages throughout the country during the last few years and in all cases, villagers have provided the labour and cost of installation on "self-

help" basis. As stated in the National Development plan, such an innovation is also very likely to attract government funding to meet some costs e.g. for machinery, consultancy services, etc. Similarly, a greater potential exists for local manufacture of MHG plant than for diesel plant. This will result in tremendous cost reductions in the supply and installation of the power plant equipment. An economy measure for micro-hydro which is already receiving attention in many parts of the world is the use of unmanned stations. This would be a very significant development for the rural areas in Sierra Leone; since manpower limitations in these areas would restrict the widespread establishment of micro-hydro installations which would otherwise require constant surveillance. The work of the London based Intermediate Technology Development Group (ITDG) is of special significance here. The ITDG has identified some distinct area of development work on turbines, that by introducing new concepts and construction techniques offer greatly improved economics for small turbine construction than have hitherto been possible using traditional designs. These turbines require the use of only simple low-cost fixed nozzles which when combined with electronic control systems would avoid the need for expensive spear valves, complicated and expensive hydraulic governors; and also increases the possibilities of local manufacture. These innovations, while resulting in low material and construction costs, also result in low maintenance and operational simplicity requirement minimal technical knowhow as can be easily developed amongst the rural population. The establishment of the Sierra Leone National Workshop would further make easier, local manufacturing efforts. One factor which can offset the advantages of the use of MHG plants is its distance from the load center. Here again, this is not likely to make an appreciable

impact on economics since in general, most rural settlements in Sierra Leone are situated near streams and there is no need for long transmission lines. An important impediment to the widespread use of micro-hydro installations is the possibility of suitable streams drying up completely during dry seasons. The successful exploitation of the potentials of such streams would require high civil engineering co ts in constructing reliable dams and reservoirs and if possible, the exploitation of ground-water sources.

The use of small-water turbines and generators for providing power in the rural settlements of Sierra Leone is gradually gaining acceptance. Recognising the potential value of small-scale hydropower for rural development, the Faculty of Engineering of the Univerisy of Sierra Leone has instituted a Research and Development programme with a view of developing adequate capabilities in this field to allow the faculty to initiate in collaboration with related institutions, full manufacturing and advisory services for the installation of MHG plants with capacities appropriate to our rural requirements.

THE UNIVERSITY AS PROJECT

The use of indigenous local groups for advisory and consultancy services to technical problems in a developing country has a number of advantages. A local group is more likely to be aware of and sympathetic to national development priorities, and they are better able to estimate the appropriate technical solution given the country's stage of development. Also, a local group is better placed to use local inputs of resources and equipment to meet these ends. But there can be found very few institutions having adequate potential capabilities to offer such services in a developing country given the diverse nature of problems involved. In Sierra Leone, perhaps the Faculty of Engineering of the University is the only institution with this capability that can, and that has so far taken the initiative to institute a research and development group with aspirations wholly directed towards advising on, and devising solutions to the country's many technological problems. With this awareness of the potential of this faculty in national development, it has for a long time established a research body ASTRAD (Advisory services for Technology, Research and Development), to which all members of the teaching staff belong. In addition, ASTRAD has an active liason and has in the past co-operated in offering advice and other services with other professional bodies outside the University through the Sierra Leone National Association of Science and Technology to some national technological problems.

One area in which the group has shown a lot of concern is the development of the country's resources to meet the growing energy needs especially amongst the rural population which comprises three-quarters of the entire population. But Sierra Leone does not possess within its borders any known substantial energy resource other than waterpower and of course direct solar energy.

These considerations prompted the Faculty of Engineering to investigate the possibilities of developing a scheme that would depend on the country's vast water potential as energy input. This alternative was chosen on the basis of its performance in other countries and because it has the greatest potential in terms of cost-effectiveness, availability of resources and the long-term requirements of power in rural areas. Many sites can be identified where small hydroelectric units can be installed to tap this energy source for use by rural inhabitants.

A recent survey by Motor-Columbus consulting Engineers reveals that there is an abundance of sites having high waterpower potentials especially for the development of micro-hydro power that would be suitable for producing both electrical energy and direct mechanical rotary power. The Faculty micro-hydropower development group aims at designing a micro-hydro scehme most apt for the development of these sites especially for rural applications and at costs within the capacity of rural communities to acquire through aided self-help efforts. As a result, a programme has been initiated with the aim of designing and developing a micro-hydro scheme using locally available resources. Present designs of micro-hydro generation schemes would be very expensive for applications in villages. It would therefore be necessary both to modify present designs where necessary and to design entire units which would lend the scheme amenable to home manufacture of vital components; with a view of achieving appreciable installation and material cost reductions. Wherever possible, local resources both in terms of materials and facilities will be exploited to the full and where applicable, villagers are to be involved to the maximum in the implimentation of

the project. They will also be trained to run and maintain the schemes themselves. This in our view is the most realistic approach to the problem.

As an offshoot to this development, it is also intended to develop end-use applications for the resulting electrical energy. Attempts will be made to upgrade traditional crafts practised at village level, which are major economic activities e.g. carpentry, blacksmithing, food preservation, weaving etc. so that electricity will be used as substitute energy input. The only critera for the selection of villages for project implementation will be:

1. The villages energy needs and the prospect for improving these needs.
2. Availability of energy resources i.e. streams with adequate head and having perennial flow characteristics.
3. Village enthusiasm and interest in participating. The ability and readiness of villagers to participate in the implementation, maintenance and smooth running of the system is a vital consideration.
4. Social utility of the project - A complete assessment of social factors involved in the villages capacity to make good use of the system is important.
5. The economic viability of the project in terms of the ability of the village community to pay back for the amenity if fund procurement was originally through a loan. Such loans can be obtained through the National Development Bank for rural development. It is however envisaged that most rural settlements would meet material and labour costs through self-help communal efforts. It is indicated in the National Development plan that Government can make substantial

contributions under such circumstances. Where this is possible, tarriffs will be raised to meet costs for consultancy services and running costs which would be minimal since water rates would not be levied. Also, for such schemes developed through communal self-help efforts, almost everybody would be a potential user.

For the purpose of the electrification of the rural areas of Sierra Leone, most requirements would fall within the range of 20 - 500 kw. These evaluations of the domestic need for electrical energy are based on a recent market survey of selected rural settlements presently without electricity supply and for larger towns where there are existing supplies. As a basis for the evaluation, the data used were based on rural population, income per head, number of individuals per household, number of potential consumers of electrical energy etc. These data served only as guidelines, and by means of a market survey, the various towns and villages were considered individually. It would however be more appropriate both in cost terms and for the purpose of developing expertise in micro-hydro equipment manufacture and installation; for the first prototype and pilot installation to be of a smaller scale, say 10 - 50 kw. In fact, there can be found many isolated loads having demands in this range, where the alternative would otherwise be diesel plant.

ANALYSIS OF ACTIVITIES AND POINT OF ENTRY

The responsibility for rural industrialization is commonly shared by several departments and ministries of Government. But apart from the Ministry of Energy and Power, the Faculty of Engineering of the University is the only major local institution that has so far taken active interest in the development of small-hydroelectric plants for village use and in the general problems of rural electrification. The Faculty of Engineering, by virtue of its inter-disciplinary nature, is well placed to serve the responsibility of major initiatives and the co-ordination of efforts so that project planning and implementation can be integrated with development policies. Also, substantial skills already exist in the various ministries and their experiences could be valuable in the realization of the project.

Thus in an effort to ensure the success of this project, the support, co-operation and involvement of relevant Government ministries and related institutions has been sought and established. These include the Sierra Leone Electricity Corporation, Land Resources Survey, Government National Workshop, the National Development Bank, and the ministries of Agriculture and Forestry, Energy and Power, Interior, Development and Economic planning, Social Welfare and Rural Development, Works and the Ministry of National Resources. Initial contacts have been very successful and detailed proposals are under preparation to give a fuller insight into the aspirations of the Faculty in research and development work on micro-hydro generation schemes. By so doing, the Faculty hopes to arise the awareness of government through its ministries and para-statals; of the potentialities in the use of micro-hydro plants for rural electrification and the possibilities for the establishment of a local manufacturing industry

for these plants. Such involvement by Government institutions will make the task of surveys, eventual financing and country-wide applications easier and it will also facilitate easier enlistment of village support and co-operation.

The methodology and implimentation strategy has also been defined and formulated. Essentially, the faculty will be involved in the design of a cheap and reliable micro-hydro generation scheme which will lend itself better to local manufacture and maintenance in our rural areas. In so doing, the traditional approach of scaling down large systems will be dispensed with and some modifications of existing plants and concepts togehter with other concepts appropriate to our local requirements will be adopted. This will require knowledge of a wide range of present designs and the selection of designs whose features are closest to fulfilling the requirements of the scheme envisaged. Accordingly, some collaboration with the London based Intermediate Technology Development Group (ITDG) has been established and through this collaboration, a member of the research team received three weeks first hand training in micro-hydro power technology on existing sites in the West of England where the ITDG has been involved in the installation of some plants. The ITDG has also shown willingness to share with the faculty research group, its long standing experience in micro-hydropower Technology. A scheme has been developed by the ITDG which is of particular interest to the development of research and implimentation capabilities of the faculty since the scheme has many features appropriate to rural applications in Sierra Leone. In particular, the use of simple turbines and electronic governors and controller in the ITDG plants greately simplifies the design and offers appreciable cost-reductions while at the same time improving the chances of local manufacture. It has been proposed to install a pilot demonstration

plant of this system here in Sierra Leone from which tests and modifications will be made to make the system more appropriate to applications in our rural areas. At the same time, this will give an opportunity for the research team to build and improve further, its research and development capabilities in micro-hydro technology to a stage where further fundamental developments on a country-wide scale can take off. After a period of experimentation on a pilot plant during which any short-comings can be identified and corrected, a country-wide survey will be embarked upon.

In addition to establishing and developing a local manufacturing capability, it would also be necessary to make an inventory of potential micro-hydro sites, their monthly and seasonal characteristics as regards variations in flow rate, quantity of water etc, and a mark survey of potential users near potential sites. This will require a lengthy survey and a detailed investigation for at least twelve months of possible sites. Initially, it would only be necessary to identify and make detailed studies of a few sites within easy reach of the faculty and at locations most suitable to serve as show-piece; since the development of these sites will only serve as a springboard from where more widespread application in the rest of the country will be undertaken. It is also contemplated that selected sites will cover all the options of high, medium and low head installations; so as to increase the applicability of micro-hydro plants throughout the country. In contemplating a widespread application of micro-hydro on a nationwide basis, due regard is given the future water resource requirements of neighbouring areas and the necessity for a co-ordinated regional planning for developing sites that lie within the same catchment area or that would depend

on the same streams for developing power supply facilities.

The rehabilitation and re-equiping of the Government National Workshop has opened a new avenue in addition to the Faculty workshop, for the manufacture and replication of micro-hydro plant components. When completed, the workshop will have most facilities appropriate to a large workhsop. The skilled manpower that is available in this workshop is also an added boost to the existing potential of the Faculty. Whilst adequate potentialities exist within the Faculty of Engineering and else where in the country for the implementation of this project financial constraints have caused setbacks. When these difficulties are overcome, it is envisaged that it will take three years to impliment the first phase of the project i.e. initial surveys, pilot-plant installation and testing component manufacture and prototype fabrication. There-after, more plants will be installed elsewhere on the basis of the requirements set out earlier. It is clear that with the appropriate support both from within and outside the country, very worthwhile development is possible in our neglected rural areas through the efforts of the Faculty of Engineering.

CONCLUSION

The use of small hydro generating units will provide the most meaningful source of energy for the rural areas of Sierra Leone. If the tremendous potential for the use of micro-hydro plants as the basis for rural electrification in Sierra Leone is to be exploited fully and if the benefit of such plants is to reach the majority of the rural population, installation costs have to be kept at the minimum. This paper has set out to outline ways by which this can be achieved in Sierra Leone. In so doing, home manufacture of plant components is emphasized. The schemes should depend on local resources as far as possible. Stations must be built with funds accumulated locally through aided self-help efforts, agricultural production or light industry activities. Central funds should be provided only for necessary technical assistance in design, manufacturing of power generating equipment or training of future local operators. Also, local research organisations like the Faculty of Engineering of the University should be encouraged to improve their capabilities so as to provide these services and hence ensure self dependence and a long-term and widespread involvement in the establishment of micro-hydro units.

It is emphasized that, as much as possible, local inhabitants who desire this amenity should be involved in the construction, installation and running of the scheme. Construction materials will be strictly local and labour must be provided by the local inhabitants. The building of dams is avoided in as far as possible but where this is necessary, they will be either rock-filled or earth-filled structures requiring only minimum cement, steel and timber.

Despite the fact that use of micro-hydro generating sets will facilitate low-cost electricity supplies to the villages of Sierra Leone, household consumption of electricity in rural areas will remain small. To improve the demand, an equally important programme of developing end use applications of the resulting electricity is to be embarked upon by the

University research team. Such applications will include the use of electricity in small rural industries, blacksmithing, grain threshing and milling, food preservation, oil extraction, timber sawing, irrigation and water supplies etc. The use of power for these activities will be the first step towards mordernising our rural settlements and providing a climate more conducive to a rapid economic development where it will matter most.

REFERENCES

1. KAMARA, D.L.T. : Micro-hydropower development; a solution to Sierra Leone's rural electrification. Con. on Appropriate Technology, Freetown, Sierra Leone. July, 1978.

2. LAWRENCE, E.D. & PILGRIM, J.W. : The transfer of small - scale hydroelectric technology. Proc. conference on small - scale energy for developing countries. Reading, U.K. January, 1979.

3. MOTOR - COLUMBUS CONSULTING ENGINEERS. INC. : The strenthening of the Sierra Leone electricity Corporation. November, 1971.

4. INTERMEDIATE TECHNOLOGY: DEVELOPMENT GROUP (I.T.D.G.), LONDON. : Advisory and consultancy capabilities in the field of small - scale hydro-electric power generation.

5. ARMSTRONG EVANS,R.J. ; SMALL SCALE WATER POWER SCHEMES. EVANS ENGINEERING SERVICES, LAUNCETON, U.K.